# Precision, Unity-Gain Differential Amplifier

# AMP-03

## FEATURES

- High CMRR ..... 100dB Typ
- Low Nonlinearity ..... 0.001% Max
- Low Distortion ..... 0.001% Typ
- Wide Bandwidth ..... 3MHz Typ
- Fast Slew Rate ..... 9.5V/μs Typ
- Fast Settling (0.01%) ..... 1μs Typ
- Low Cost

## APPLICATIONS

- Summing Amplifiers
- Instrumentation Amplifiers
- Balanced Line Receivers
- Current-Voltage Conversion
- Absolute Value Amplifier
- 4-20mA Current Transmitter
- Precision Voltage Reference Applications
- Lower Cost and Higher Speed Version of INA105

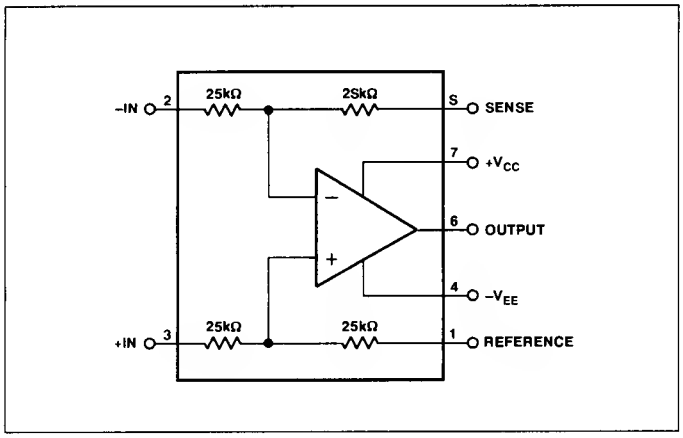
## ORDERING INFORMATION †

| PACKAGE | | OPERATING TEMPERATURE RANGE |
|---|---|---|
| TO-99 | PLASTIC 8-PIN | |
| AMP03BJ* | – | MIL |
| AMP03FJ | AMP03GP | XIND |

* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

† Burn-in is available on commercial and industrial temperature range parts in plastic DIP, and TO-can packages.

## FUNCTIONAL DIAGRAM



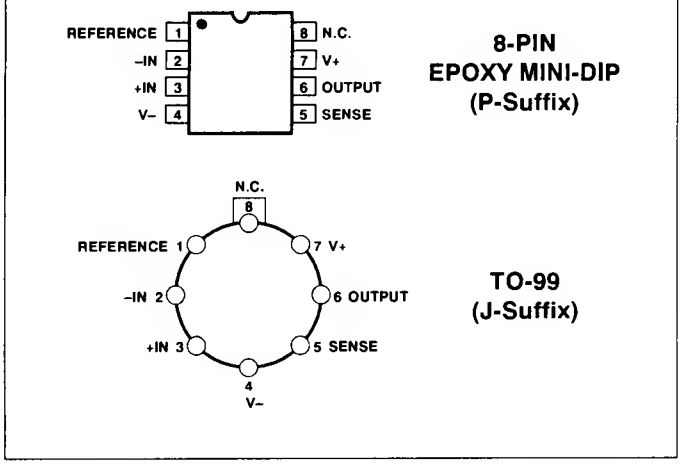

## GENERAL DESCRIPTION

The AMP-03 is a monolithic unity-gain, high-speed differential amplifier. Incorporating a matched thin-film resistor network, the AMP-03 features stable operation over temperature without requiring expensive external matched components. The AMP-03 is a basic analog building block for differential amplifier and instrumentation applications.

The differential amplifier topology of the AMP-03 serves to both amplify the difference between two signals and provide extremely high rejection of the common-mode input voltage. By providing common-mode rejection (CMR) of 100dB typical, the AMP-03 solves common problems encountered in instrumentation design. As an example, the AMP-03 is ideal for performing either addition or subtraction of two signals without using expensive externally-matched precision resistors. The large common-mode rejection is made possible by matching the internal resistors to better than 0.002% and maintaining a thermally symmetric layout. Additionally, due to high CMR over frequency, the AMP-03 is an ideal general amplifier for buffering signals in a noisy environment into data acquisition systems.

The AMP-03 is a higher speed alternative to the INA105. Featuring slew rates of 9.5V/μs, and a bandwidth of 3MHz, the AMP-03 offers superior performance for high speed current sources, absolute value amplifiers, and summing amplifiers than the INA105.

## PIN CONNECTIONS



## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ..... ±18V
Input Voltage (Note 2) ..... Supply Voltage
Output Short-Circuit Duration ..... Continuous
Storage Temperature Range
P, J Package ..... –65°C to +150°C
Lead Temperature (Soldering, 60 sec) ..... +300°C
Junction Temperature ..... +150°C
Operating Temperature Range
AMP-03B ..... –55°C to +125°C
AMP-03F, AMP-03G ..... –40°C to +85°C

| PACKAGE TYPE | $\Theta_{JA}$ (Note 3) | $\Theta_{JC}$ | UNITS |
|---|---|---|---|
| TO-99 (J) | 150 | 18 | °C/W |
| 8-Pin Plastic DIP (P) | 103 | 43 | °C/W |

**NOTES:**
1. Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.
2. For supply voltages less than ±18V, the absolute maximum input voltage is equal to the supply voltage.
3. $\Theta_{JA}$ is specified for worst case mounting conditions, i.e., $\Theta_{JA}$ is specified for device in socket for TO and P-DIP packages.

## ELECTRICAL CHARACTERISTICS at $V_S$ = ±15V, $T_A$ = +25°C, unless otherwise noted.

| | | | AMP-03F | | | AMP-03B | | | AMP-03G | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| Offset Voltage | $V_{OS}$ | $V_{CM}$ = 0V | –400 | 10 | 400 | –700 | 20 | 700 | –750 | 25 | 750 | µV |
| Gain Error | | No Load, $V_{IN}$ = ±10V, $R_S$ = 0Ω | – | 0.00004 | 0.008 | – | 0.00004 | 0.008 | – | 0.001 | 0.008 | % |
| Input Voltage Range | IVR | | ±20 | – | – | ±20 | – | – | ±20 | – | – | V |
| Common-Mode Rejection | CMR | $V_{CM}$ = ±10V | 85 | 100 | – | 80 | 95 | – | 80 | 95 | – | dB |
| Power Supply Rejection Ratio | PSRR | $V_S$ = ±6V to ±18V | – | 0.6 | 10 | – | 0.6 | 10 | – | 0.7 | 10 | µV/V |
| Output Swing | $V_O$ | $R_L$ = 2kΩ | ±12 | ±13.7 | – | ±12 | ±13.7 | – | ±12 | ±13.7 | – | V |
| Short-Circuit Current Limit | $I_{SC}$ | Output Shorted To Ground | +45/–15 | – | – | +45/–15 | – | – | +45/–15 | – | – | mA |
| Small-Signal Bandwidth (–3dB) | BW | $R_L$ = 2kΩ | – | 3 | – | – | 3 | – | – | 3 | – | MHz |
| Slew Rate | SR | $R_L$ = 2kΩ | 6 | 9.5 | – | 6 | 9.5 | – | 6 | 9.5 | – | V/µs |
| Capacitive Load Drive Capability | $C_L$ | No Oscillation | – | 300 | – | – | 300 | – | – | 300 | – | pF |
| Supply Current | $I_{SY}$ | No Load | – | 2.5 | 3.5 | – | 2.5 | 3.5 | – | 2.5 | 3.5 | mA |

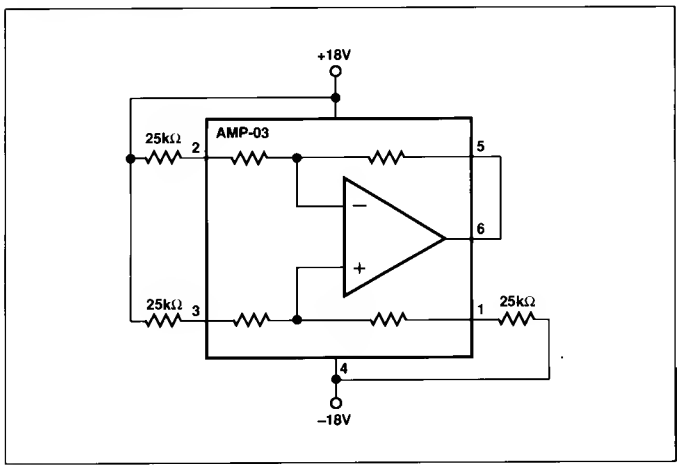
## ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $-55°C \leq T_A \leq +125°C$ for B grade. Continued

| | | | AMP-03B | | | |
|---|---|---|---|---|---|---|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
| Offset Voltage | $V_{OS}$ | $V_{CM} = 0V$ | −1500 | 150 | 1500 | µV |
| Gain Error | | No Load, $V_{IN} = \pm 10V$, $R_S = 0\Omega$ | – | 0.0014 | 0.02 | % |
| Input Voltage Range | IVR | | ±20 | – | – | V |
| Common-Mode Rejection | CMR | $V_{CM} = \pm 10V$ | 75 | 95 | – | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 6V$ to $\pm 18V$ | – | 0.7 | 20 | µV/V |
| Output Swing | $V_O$ | $R_L = 2k\Omega$ | ±12 | ±13.7 | – | V |
| Slew Rate | SR | $R_L = 2k\Omega$ | – | 9.5 | – | V/µs |
| Supply Current | $I_{SY}$ | No Load | – | 3.0 | 4.0 | mA |

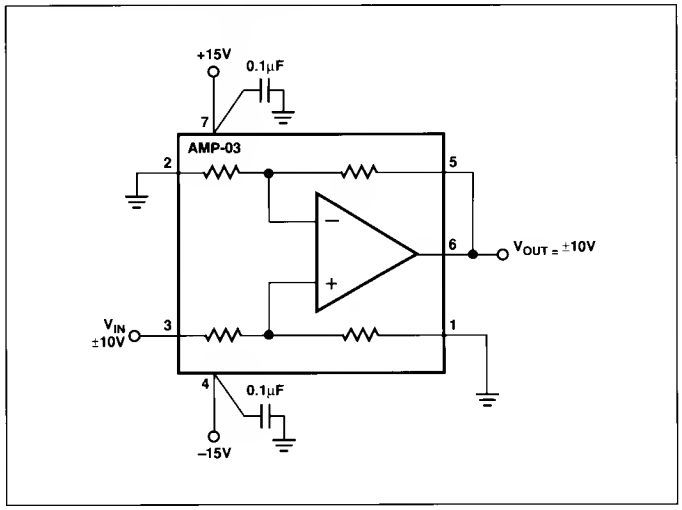
## ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $-40°C \leq T_A \leq +85°C$ for F and G grades.

| | | | AMP-03F | | | AMP-03G | | | |
|---|---|---|---|---|---|---|---|---|---|
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | MIN | TYP | MAX | UNITS |
| Offset Voltage | $V_{OS}$ | $V_{CM} = 0V$ | −1000 | 100 | 1000 | −2000 | 200 | 2000 | µV |
| Gain Error | | No Load, $V_{IN} = \pm 10V$, $R_S = 0\Omega$ | – | 0.0008 | 0.015 | – | 0.002 | 0.02 | % |
| Input Voltage Range | IVR | | ±20 | – | – | ±20 | – | – | V |
| Common-Mode Rejection | CMR | $V_{CM} = \pm 10V$ | 80 | 95 | – | 75 | 90 | – | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 6V$ to $\pm 18V$ | – | 0.7 | 15 | – | 1.0 | 15 | µV/V |
| Output Swing | $V_O$ | $R_L = 2k\Omega$ | ±12 | ±13.7 | – | ±12 | ±13.7 | – | V |
| Slew Rate | SR | $R_L = 2k\Omega$ | – | 9.5 | – | – | 9.5 | – | V/µs |
| Supply Current | $I_{SY}$ | No Load | – | 2.6 | 4.0 | – | 2.6 | 4.0 | mA |

## BURN-IN CIRCUIT

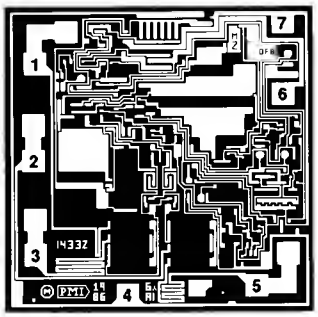



## SLEW RATE TEST CIRCUIT



# AMP-03

## DICE CHARACTERISTICS




**DIE SIZE 0.076 x 0.076 inch, 5,776 sq. mils**
**(1.93 x 1.93 mm, 3.73 sq. mm)**

1. **REFERENCE**
2. **–IN**
3. **+IN**
4. **V–**
5. **SENSE**
6. **OUTPUT**
7. **V+**
8. **N.C.**

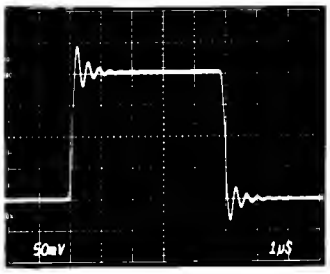
## WAFER TEST LIMITS at $V_S$ = ±15V, $T_A$ = +25°C unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | AMP-03BC LIMITS | UNITS |
|---|---|---|---|---|
| Offset Voltage | $V_{OS}$ | $V_S$ = ±18V | 0.5 | mV MAX |
| Gain Error | | No Load, $V_{IN}$ = ±10V, $R_S$ = 0Ω | 0.008 | % MAX |
| Input Voltage Range | IVR | | ±10 | V MIN |
| Common-Mode Rejection | CMR | $V_{CM}$ = ±10V | 80 | dB MIN |
| Power Supply Rejection Ratio | PSRR | $V_S$ = ±6V to ±18V | 8 | µV/V MAX |
| Output Swing | $V_O$ | $R_L$ = 2kΩ | ±12 | V MAX |
| Short-Circuit Current Limit | $I_{SC}$ | Output Shorted To Ground | +45/–15 | mA MIN |
| Supply Current | $I_{SY}$ | No Load | 3.5 | mA MAX |

Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualifications through sample lot assembly and testing.

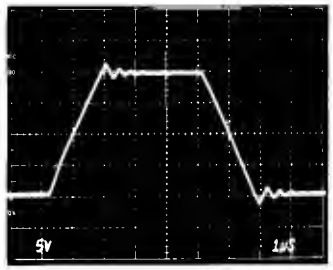
## TYPICAL PERFORMANCE CHARACTERISTICS

### SMALL-SIGNAL TRANSIENT RESPONSE



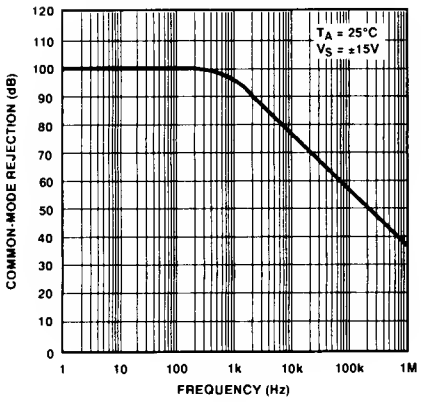

$T_A$ = +25°C
$V_S$ = ±15V

### LARGE-SIGNAL TRANSIENT RESPONSE

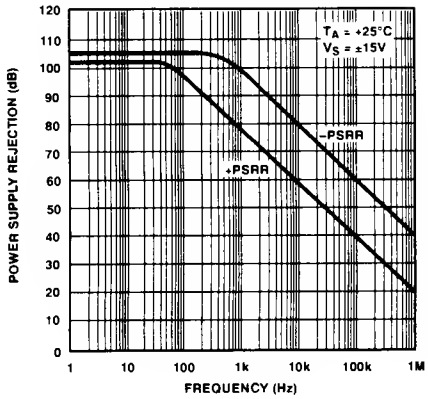



$T_A$ = +25°C
$V_S$ = ±15V

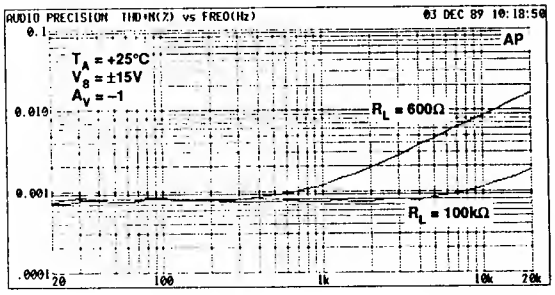
### COMMON-MODE REJECTION vs FREQUENCY



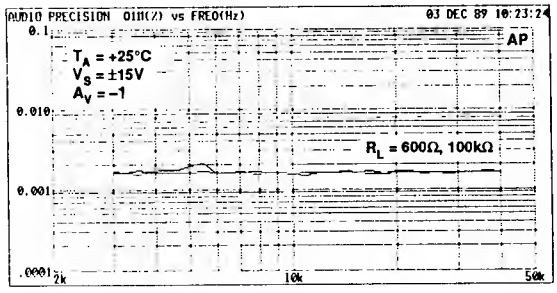

### POWER SUPPLY REJECTION vs FREQUENCY




### TOTAL HARMONIC DISTORTION vs FREQUENCY

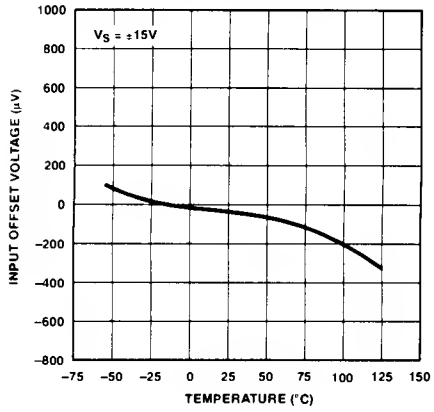



### DYNAMIC INTERMODULATION DISTORTION vs FREQUENCY

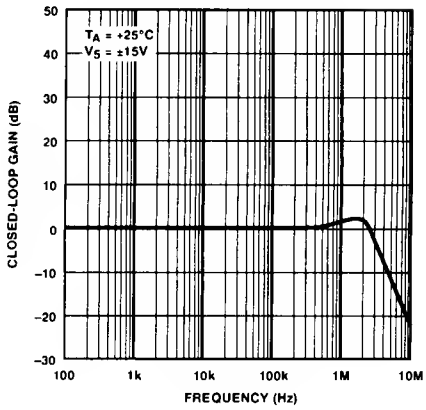


## TYPICAL PERFORMANCE CHARACTERISTICS *Continued*

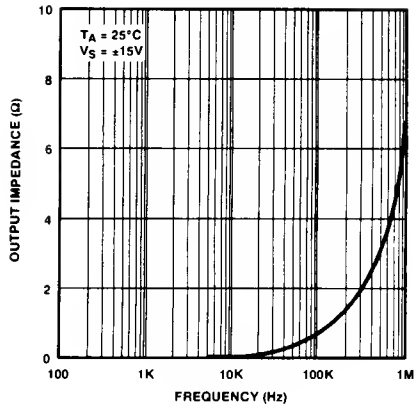
### INPUT OFFSET VOLTAGE vs TEMPERATURE



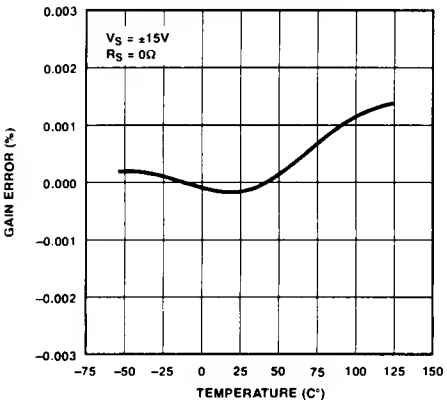

### CLOSED-LOOP GAIN vs FREQUENCY



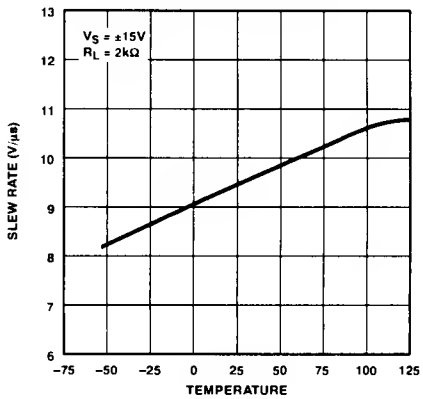

### CLOSED-LOOP OUTPUT IMPEDANCE vs FREQUENCY



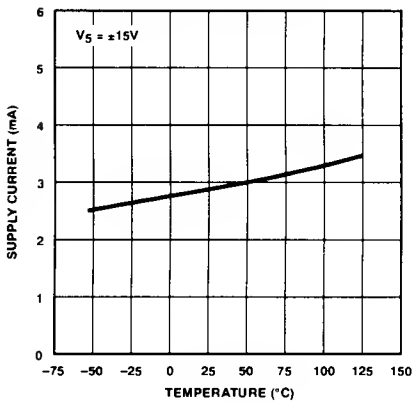

### GAIN ERROR vs TEMPERATURE



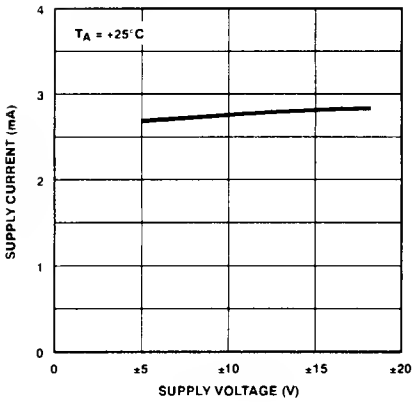

### SLEW RATE vs TEMPERATURE



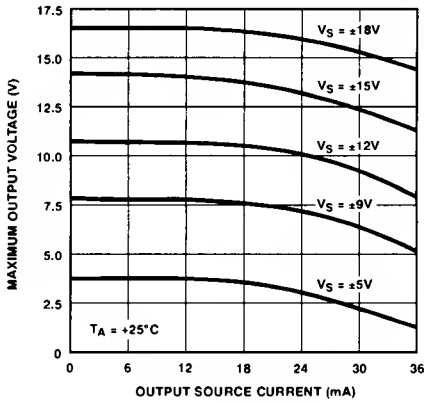

### SUPPLY CURRENT vs TEMPERATURE



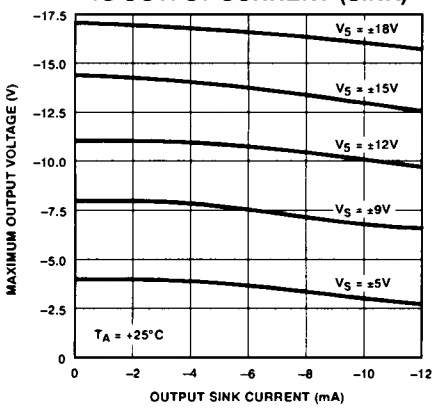

### SUPPLY CURRENT vs SUPPY VOLTAGE




### MAXIMUM OUTPUT VOLTAGE vs OUTPUT CURRENT (SOURCE)

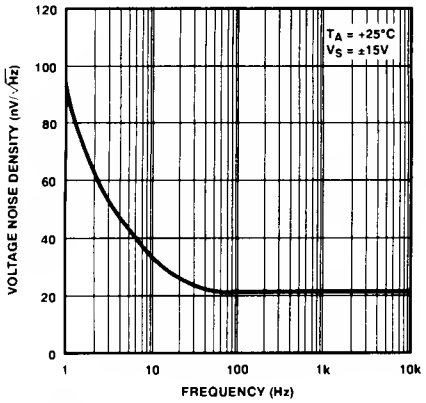



### MAXIMUM OUTPUT VOLTAGE vs OUTPUT CURRENT (SINK)

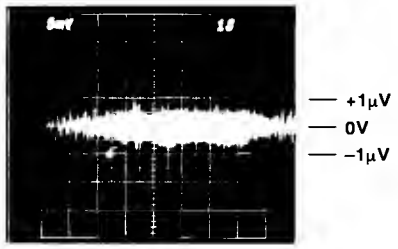


## TYPICAL PERFORMANCE CHARACTERISTICS *Continued*

### VOLTAGE NOISE DENSITY vs FREQUENCY

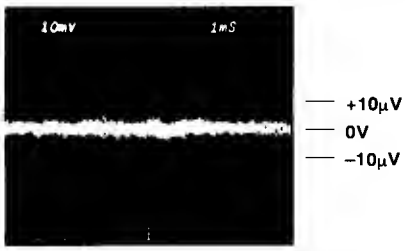



### LOW FREQUENCY VOLTAGE NOISE



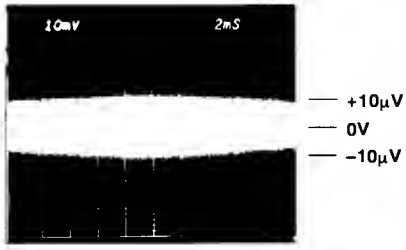

0.1 TO 10Hz PEAK-TO-PEAK NOISE

### VOLTAGE NOISE FROM 0 TO 1kHz




$T_A$ = +25°C
$V_S$ = ±15V
NOTE: EXTERNAL AMPLIFIER GAIN = 1000;
THEREFORE, VERTICAL SCALE = 10μV/DIV.

### VOLTAGE NOISE FROM 0 TO 10kHz




$T_A$ = +25°C
$V_S$ = ±15V
NOTE: EXTERNAL AMPLIFIER GAIN = 1000;
THEREFORE, VERTICAL SCALE = 10μV/DIV.

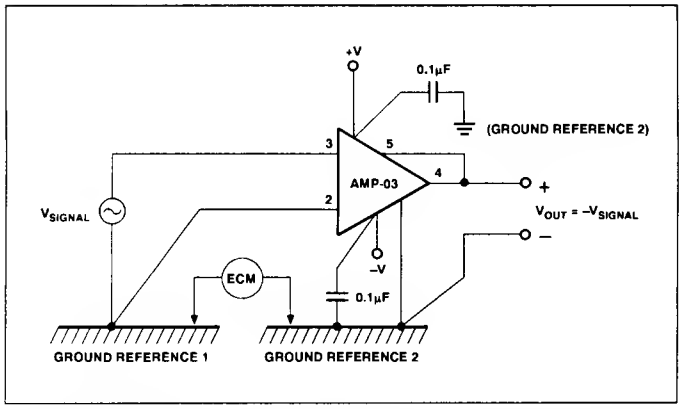



**FIGURE 1:** *AMP-03 serves to reject common-mode voltages in instrumentation systems. Common-mode voltages occur due to ground current returns. $V_{SIGNAL}$ and $E_{CM}$ must be within the common-mode range of AMP-03.*

## APPLICATIONS INFORMATION

The AMP-03 represents a versatile analog building block. In order to capitalize on fast settling time, high slew rate, and high CMR, proper decoupling and grounding techniques must be employed. Figure 1 illustrates the use of 0.1μF decoupling capacitors and proper ground connections.

### MAINTAINING COMMON-MODE REJECTION

In order to achieve the full common-mode rejection capability of the AMP-03, the source impedance must be carefully controlled. Slight imbalances of the source resistance will result in a degradation of DC CMR - even a 5Ω imbalance will degrade CMR by 20dB. Also, the matching of the reactive source impedance must be matched in order to preserve theCMRR over frequency.

## APPLICATION CIRCUITS

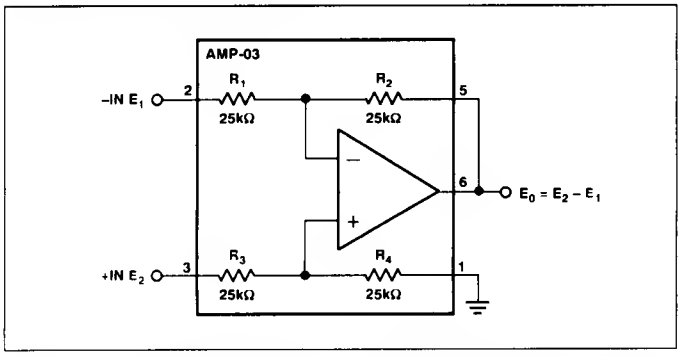



**FIGURE 2:** *Precision Difference Amplifier. Rejects Common-Mode Signal =* $\frac{[E_1 + E_2]}{2}$ *by 100dB*

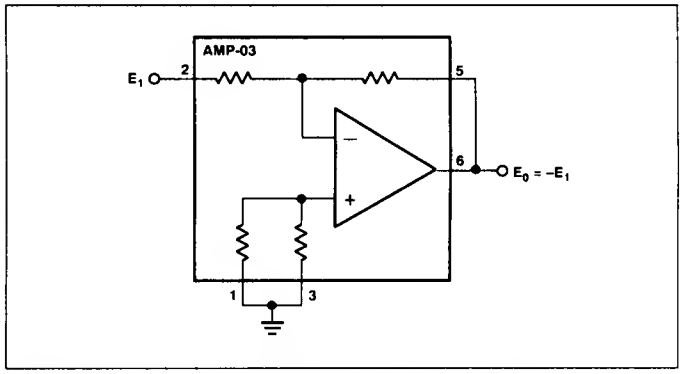



**FIGURE 3:** *Precision Unity-Gain Inverting Amplifier*

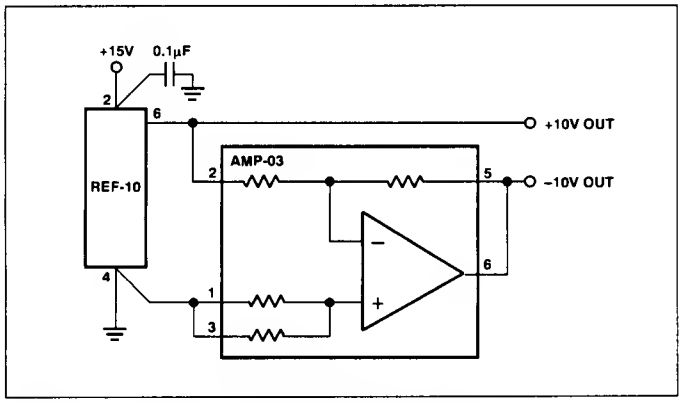



**FIGURE 4:** *±10V Precision Voltage Reference*

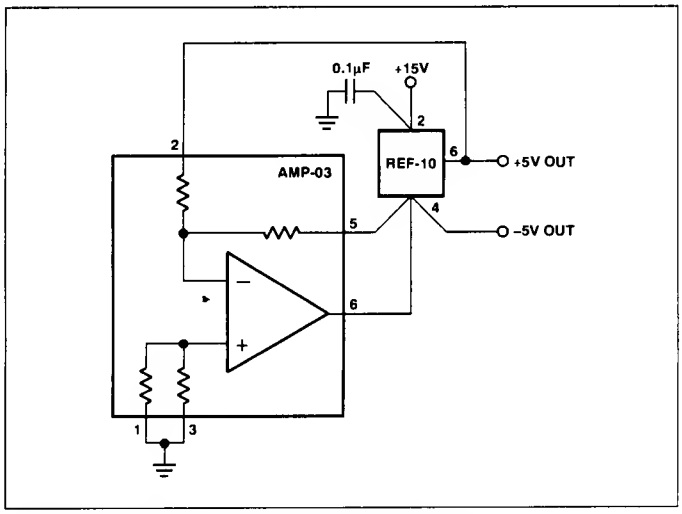



**FIGURE 5:** *±5V Precision Voltage Reference*

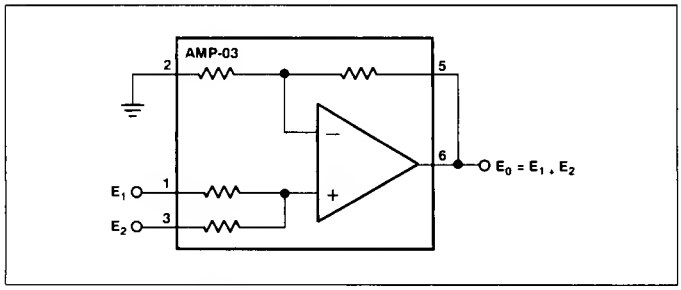



**FIGURE 6:** *Precision Summing Amplifier*

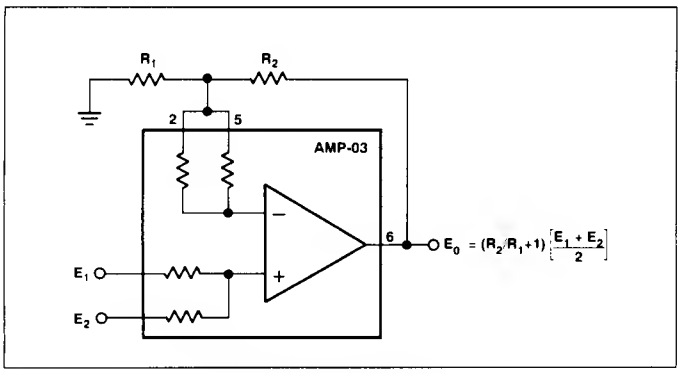



**FIGURE 7:** *Precision Summing Amplifier with Gain*

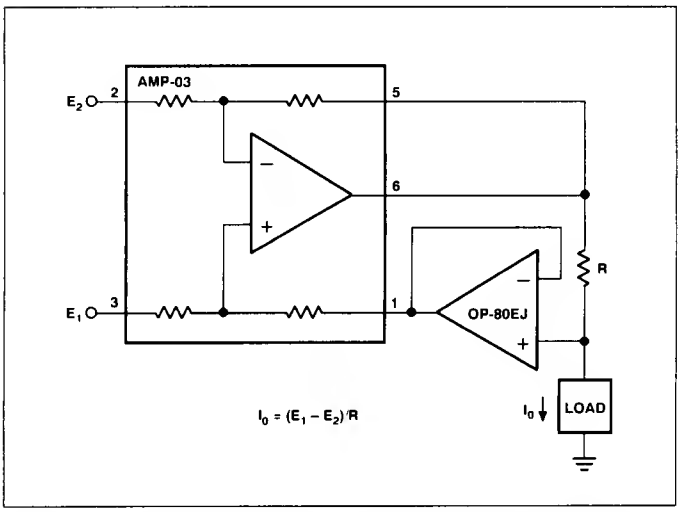



**FIGURE 8:** *Differential input voltage-to-current converter for low $I_{OUT}$. OP-80EJ maintains 250fA max. input current, allowing $I_O$ to be less than 1pA.*

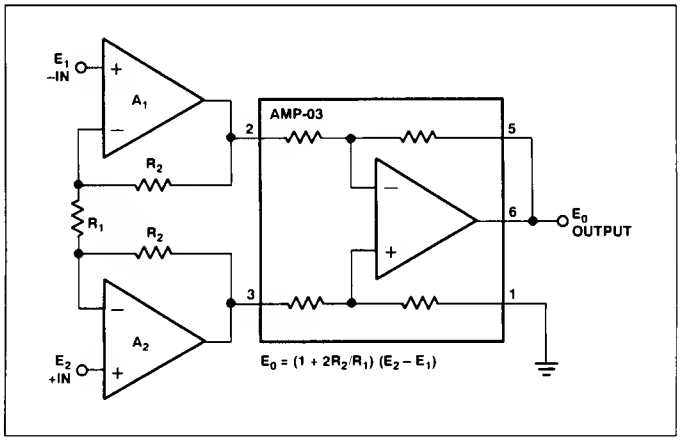



**FIGURE 9:** *Suitable instrumentation amplifier requirements can be addressed by using an input stage consisting of $A_1$, $A_2$, $R_1$ and $R_2$. The following matrix suggests a suitable amplifier.*

| SYSTEM DESIGN REQUIREMENT | SUGGESTED OP AMP FOR $A_1$ AND $A_2$ |
|---|---|
| Source impedance low, need low voltage noise performance | OP-27, OP-37<br>OP-227 (Dual Matched)<br>OP-270 (Dual)<br>OP-271<br>OP-470<br>OP-471 |
| Source impedance high ($R_S \geq 15K\Omega$), need low current noise | OP-80<br>OP-41<br>OP-43<br>OP-249<br>OP-97 |
| Require ultra-high input impedance | OP-80<br>OP-97<br>OP-41<br>OP-43 |
| Need wider bandwidth and high speed | OP-42<br>OP-43<br>OP-249 |